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Hoberman et al.

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(54) **SYNCHRONIZED RING LINKAGES**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 584 days.

This patent is subject to a terminal disclaimer.

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(22) Filed: **Oct. 12, 2004**

(65) **Prior Publication Data**

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Related U.S. Application Data

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(51) **Int. Cl.**
B25J 17/00 (2006.01)

(52) **U.S. Cl.** **74/490.05**; 428/12; 446/487

(58) **Field of Classification Search** 74/490.01, 74/490.05; 428/12; 446/487
See application file for complete search history.

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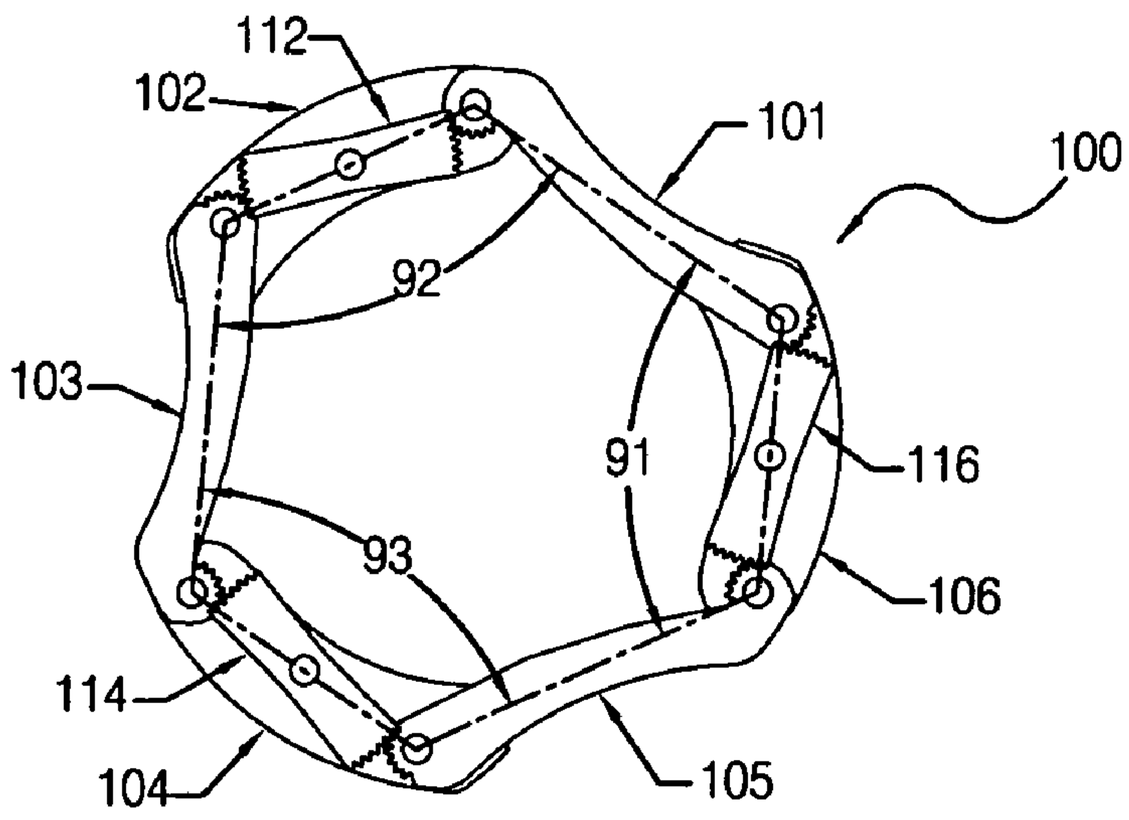
Primary Examiner—David M Fenstermacher
(74) *Attorney, Agent, or Firm*—Gottlieb, Rackman & Reisman

(57) **ABSTRACT**

A ring linkage is hereby disclosed that is comprised of at least six links, each link having at least two pivots located proximate to their ends, said links being arranged in a loop whereby each link is pivotally attached via its end pivots to two neighboring links.

The motion of the linkage is synchronized by a multiplicity of mechanical elements that serve to synchronize the relative rotation of the links in the assembly such that when a given link rotates by an angle, every second link rotates by the same angle. These synchronizing elements may be either gears, cables or belts, thus the relative angle between the every second link in the ring linkage (as defined by lines passing through their respective end pivots) remains constant and unchanging even as the position of the linkage is changed.

12 Claims, 11 Drawing Sheets



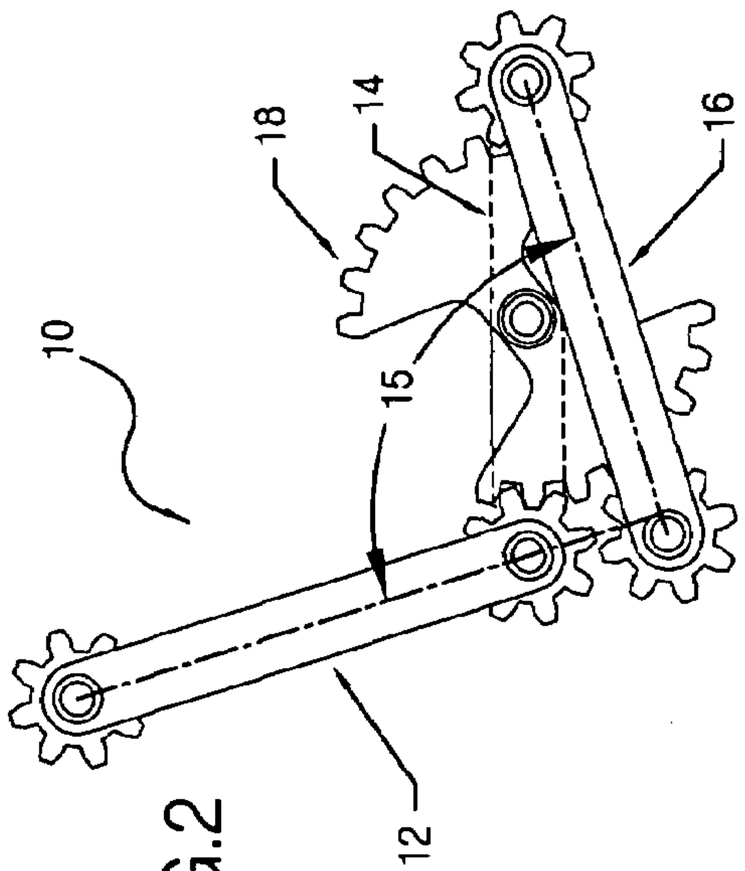


FIG.2

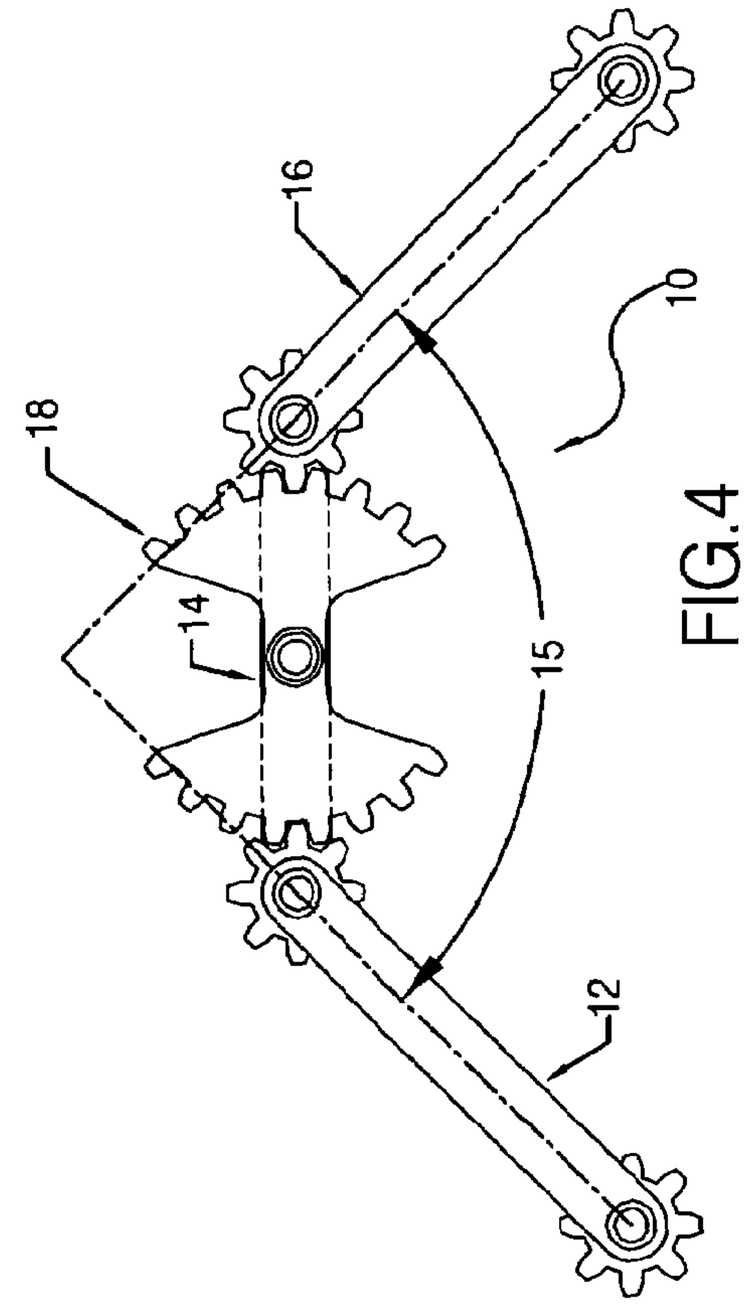


FIG.4

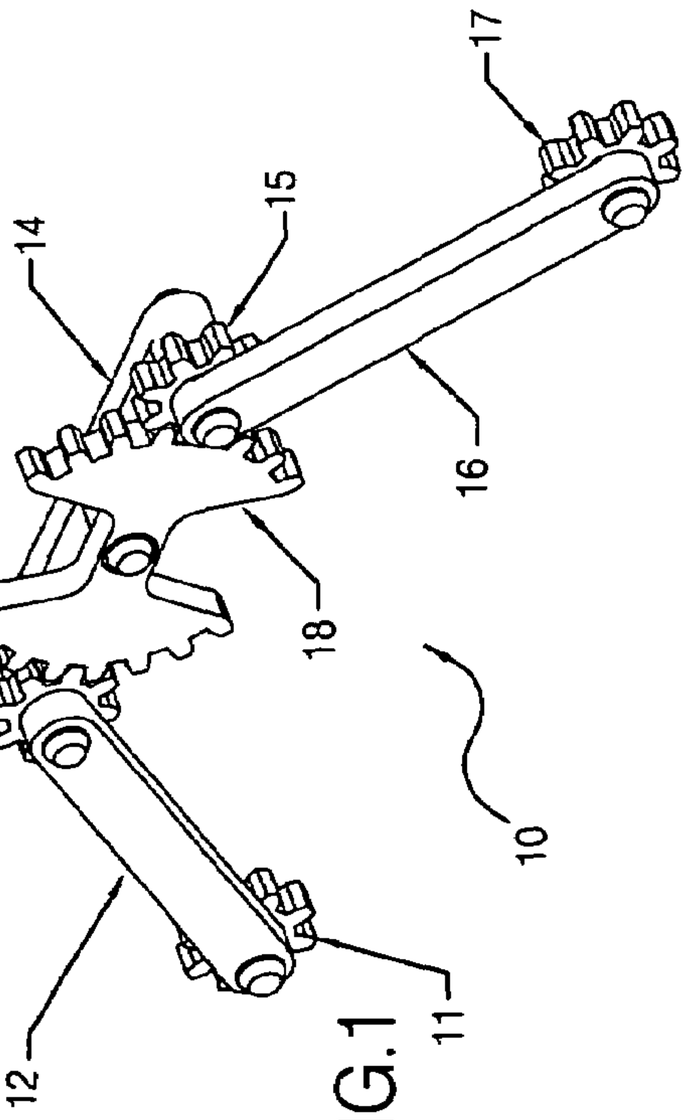


FIG.1

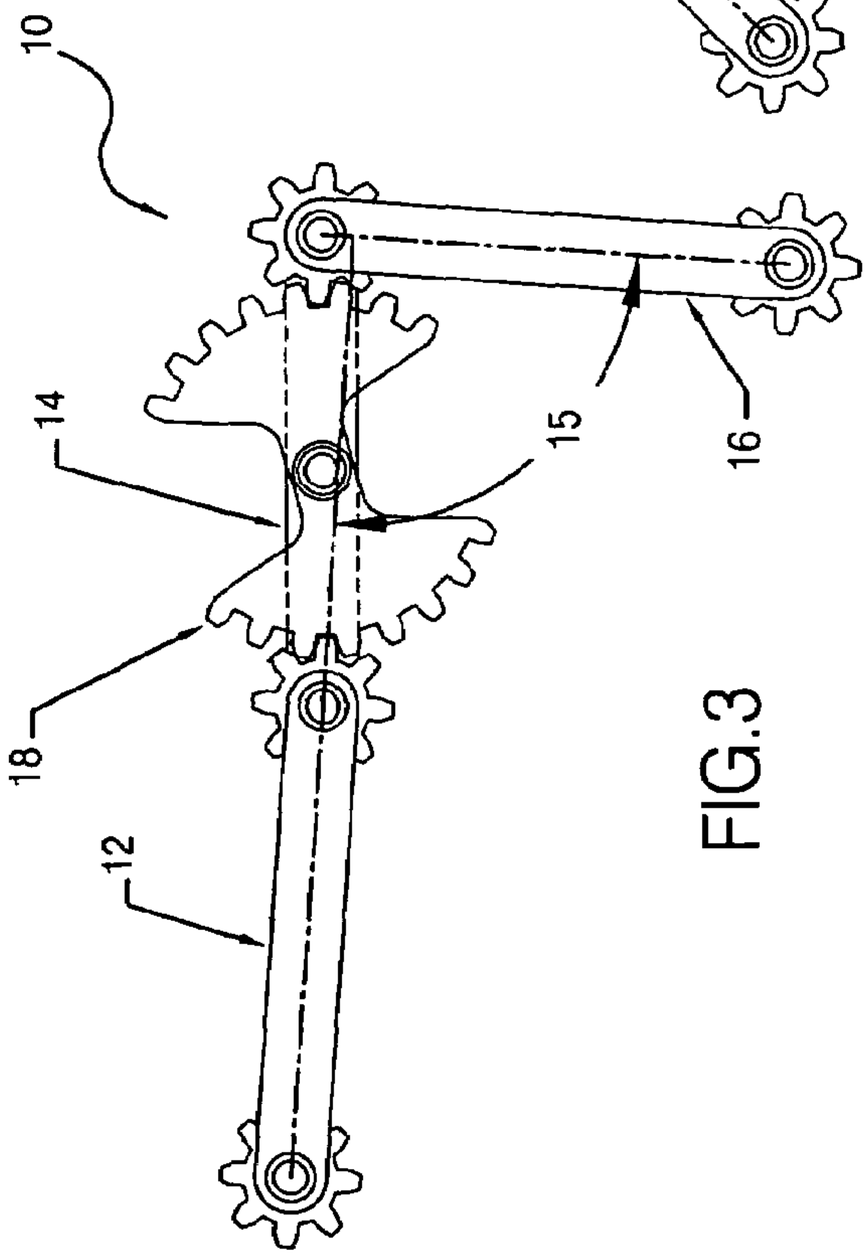


FIG.3

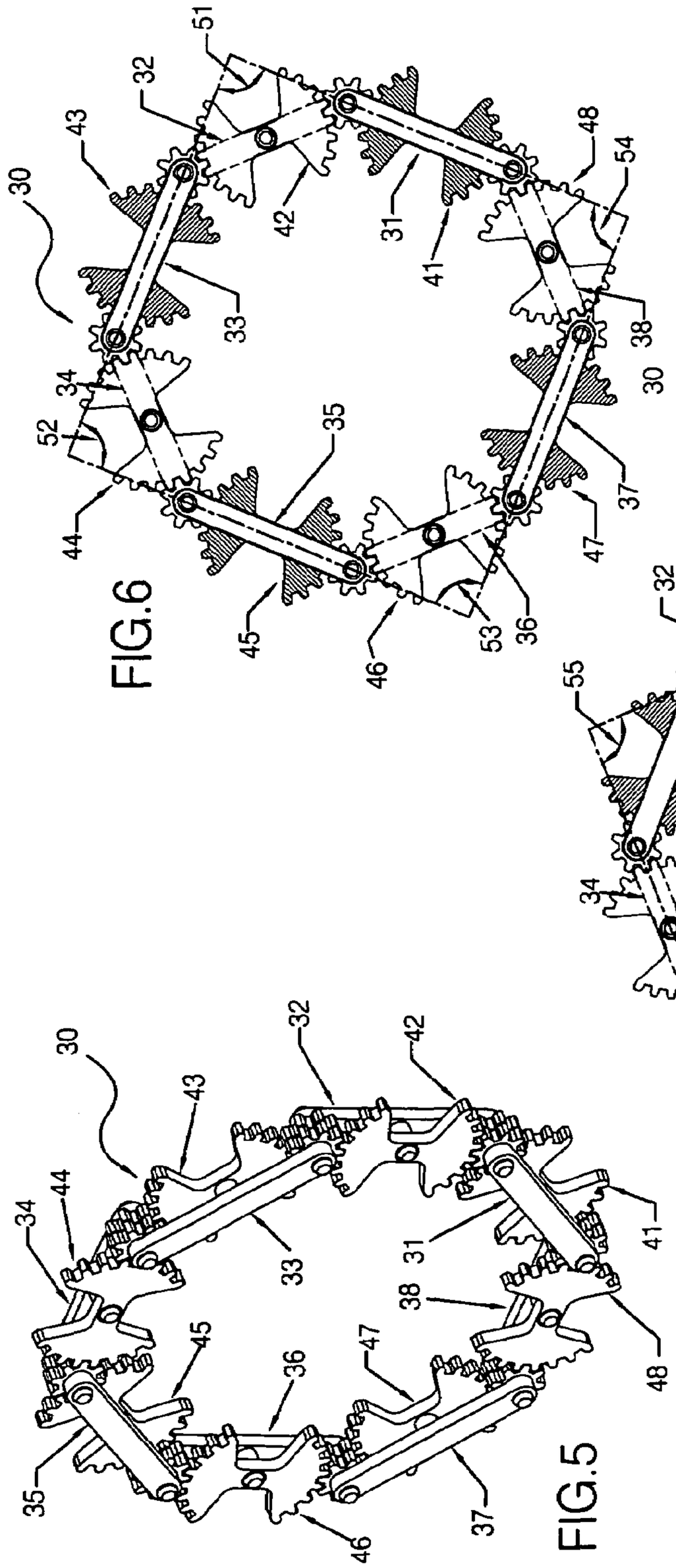


FIG.6

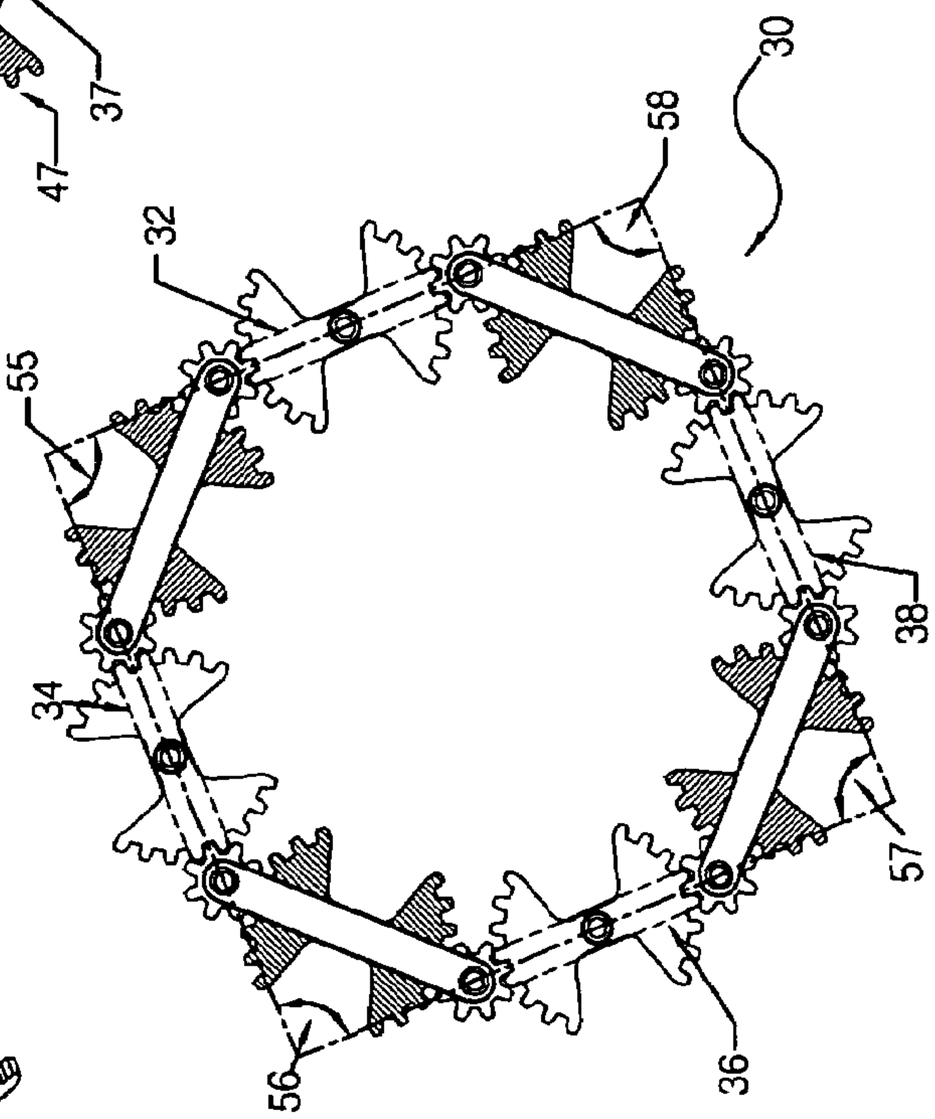


FIG.7

FIG.5

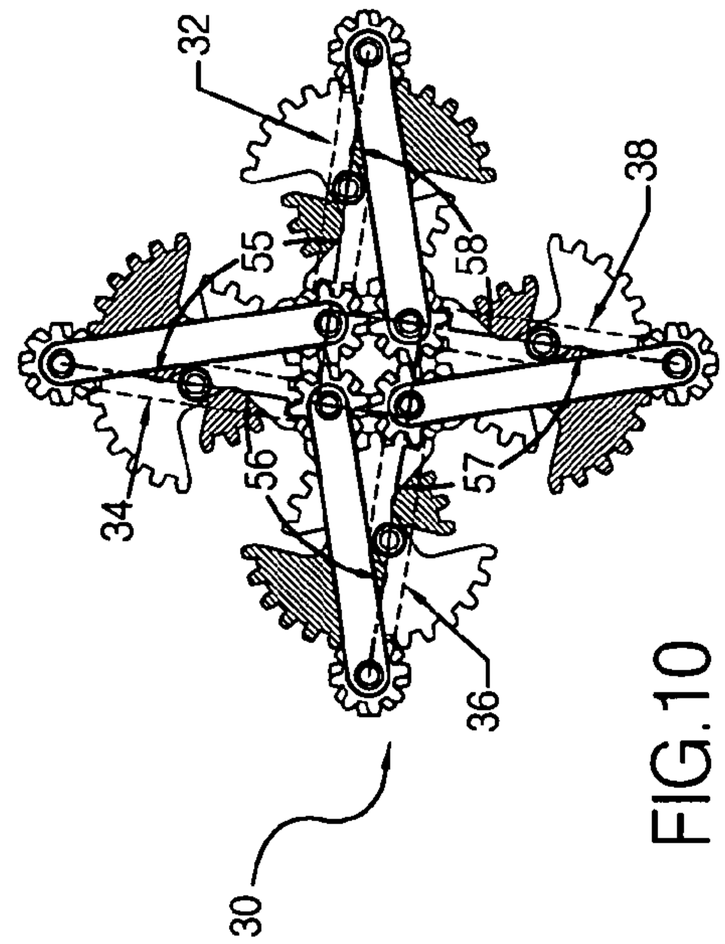


FIG.10

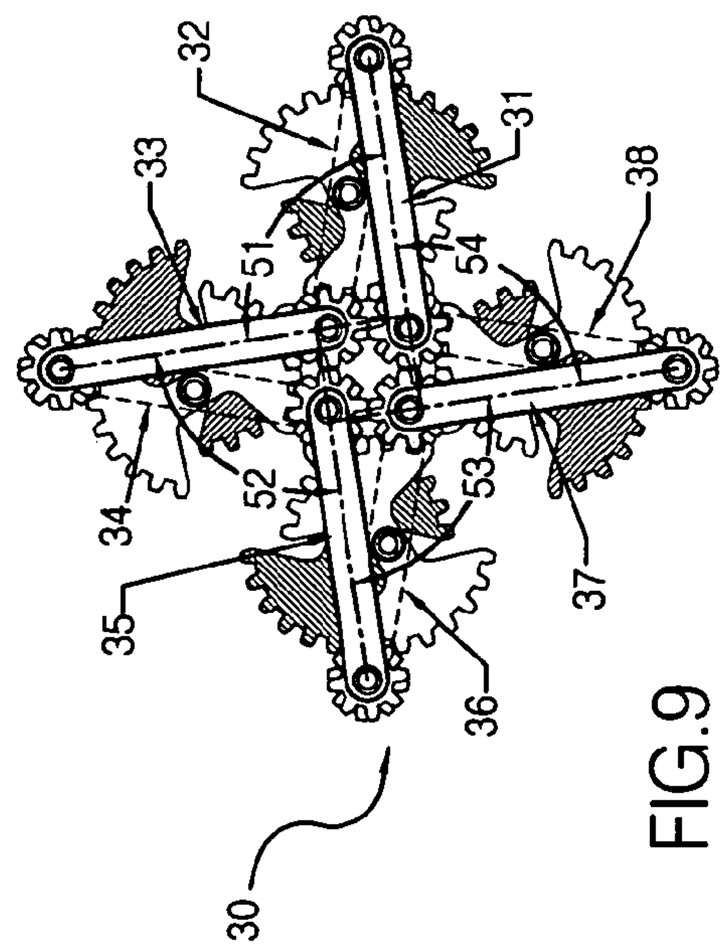


FIG.9

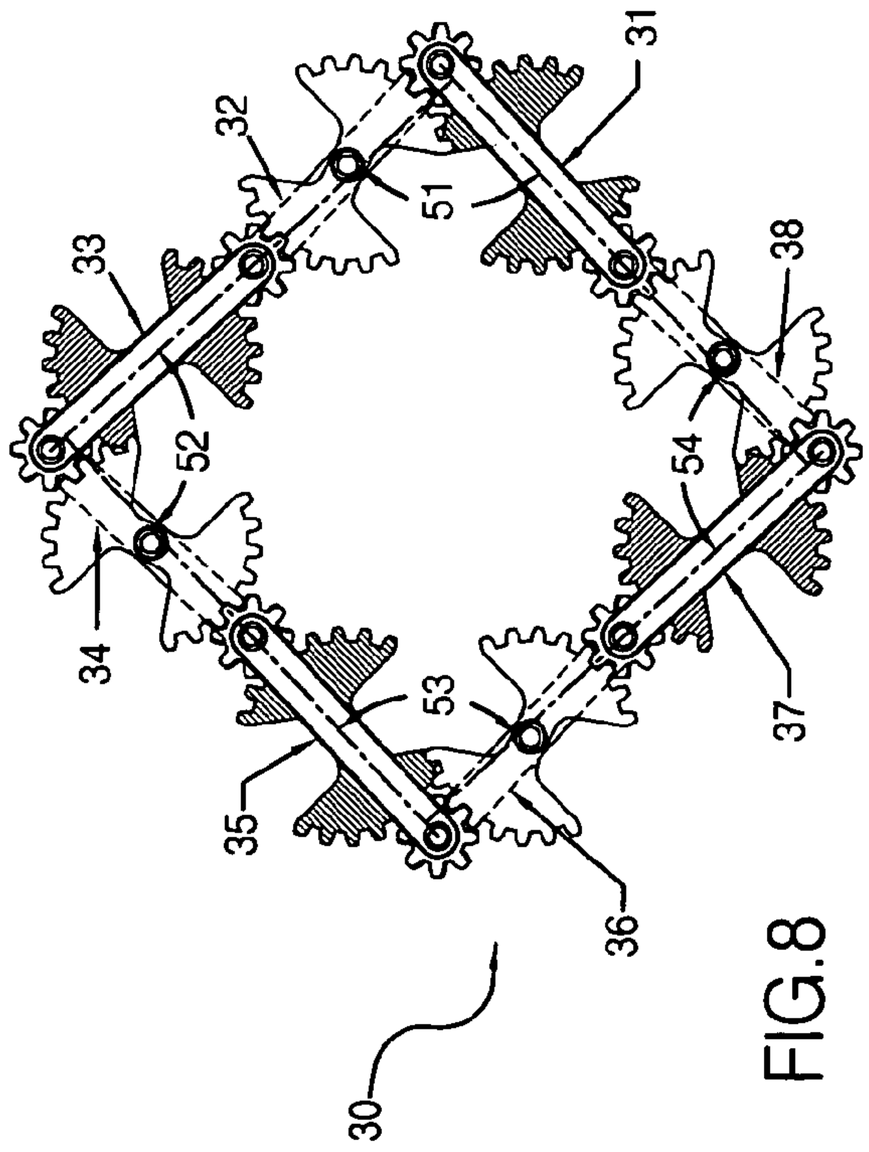


FIG.8

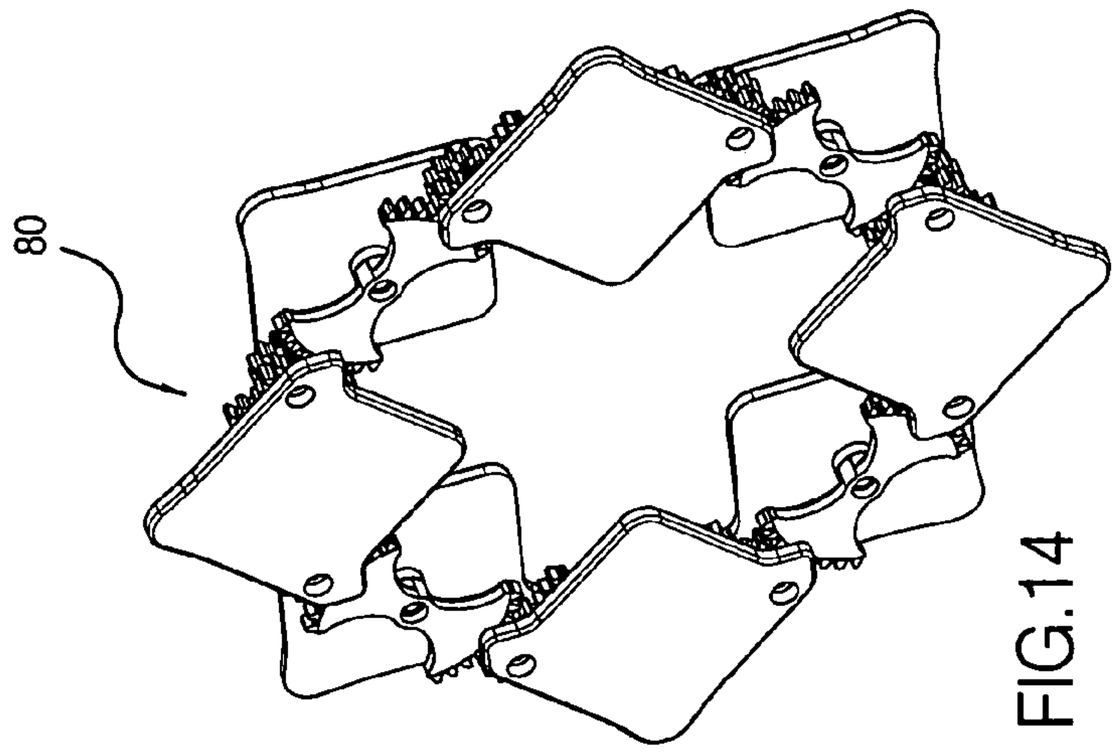


FIG.14

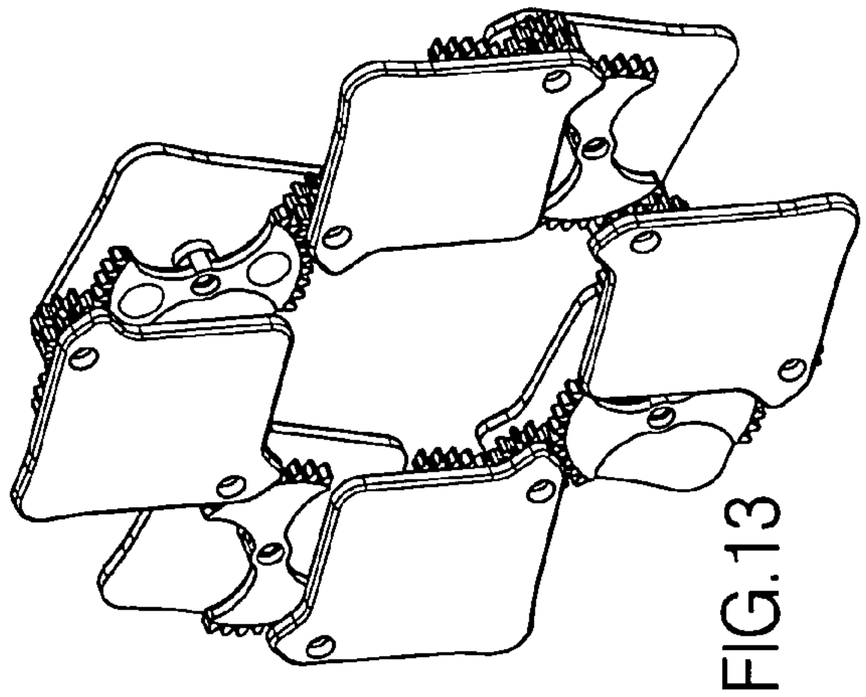


FIG.13

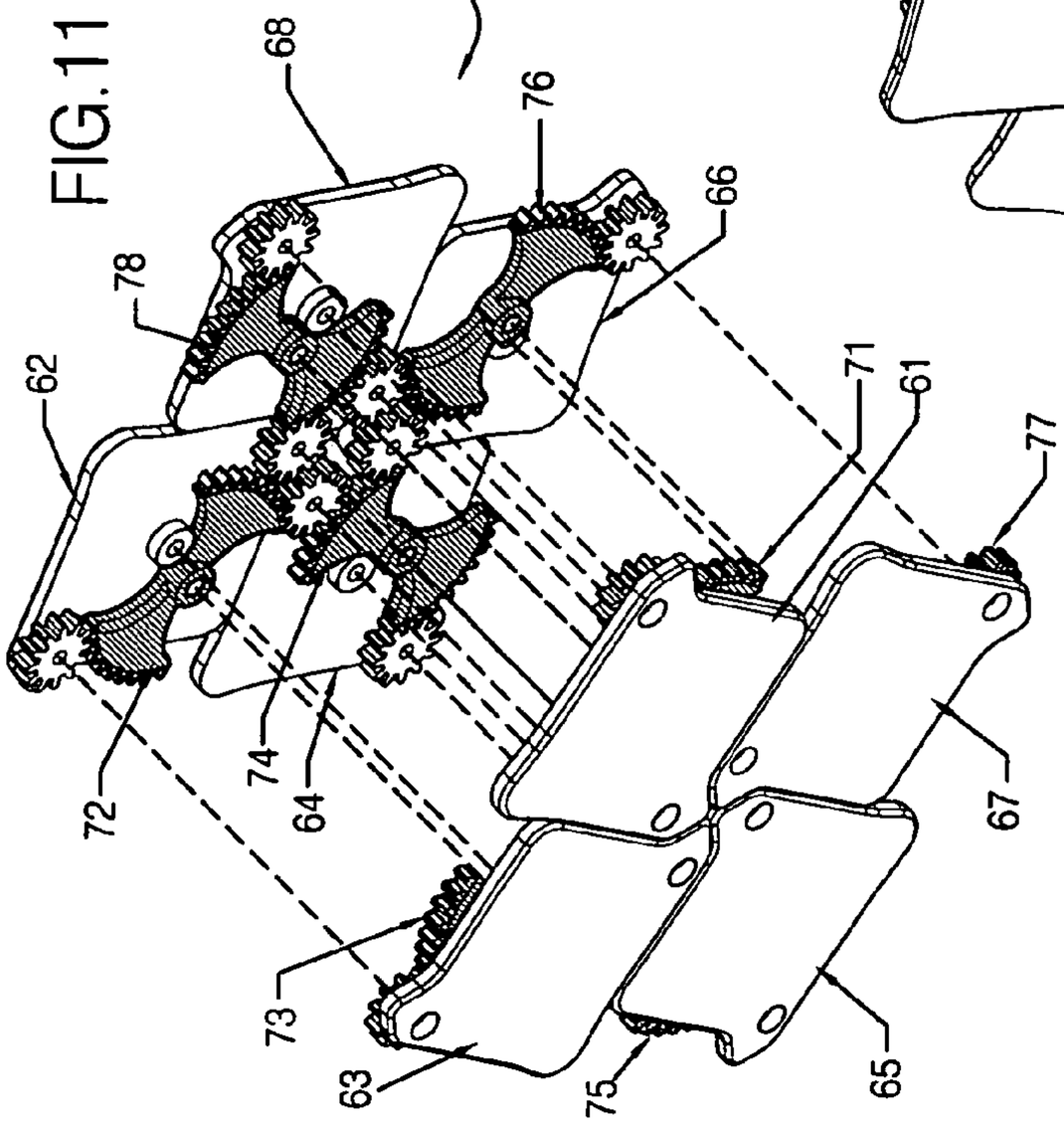


FIG.11

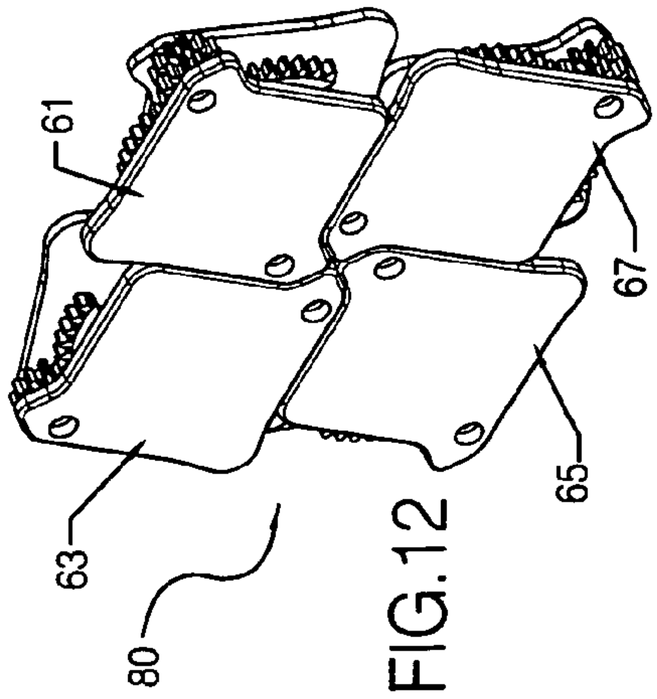


FIG.12

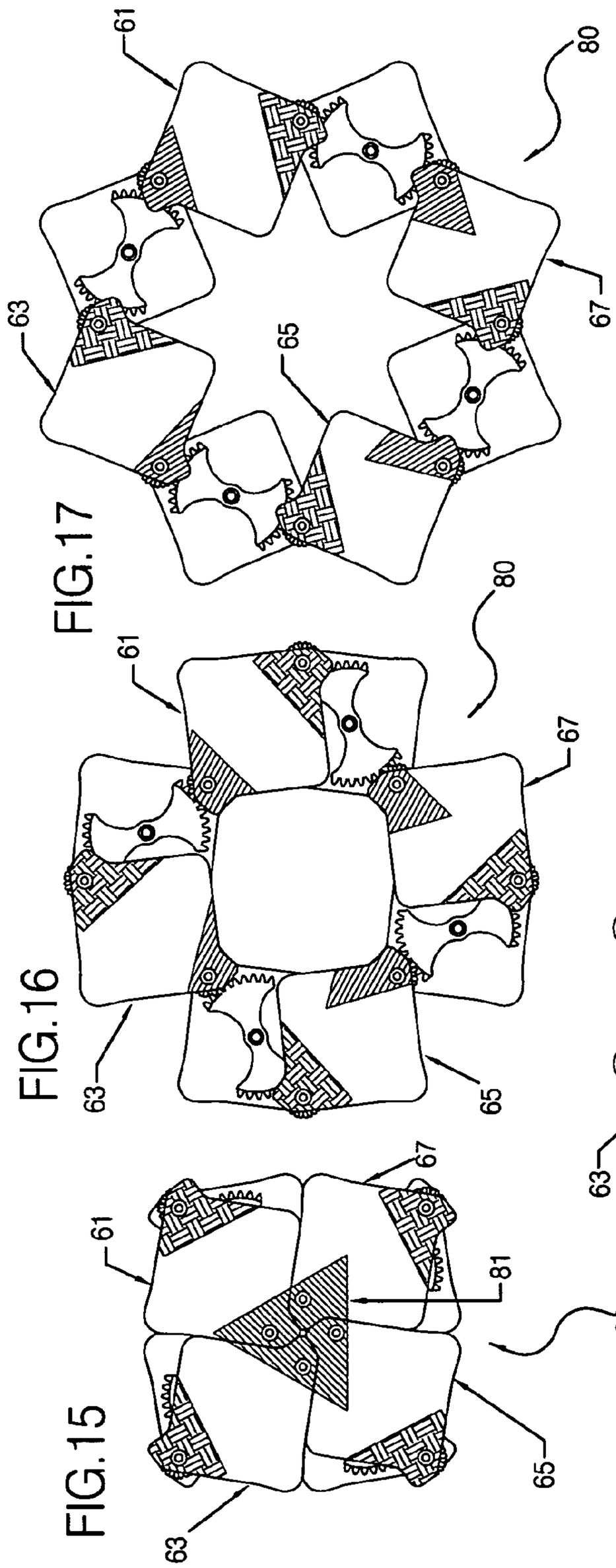


FIG.15

FIG.16

FIG.17

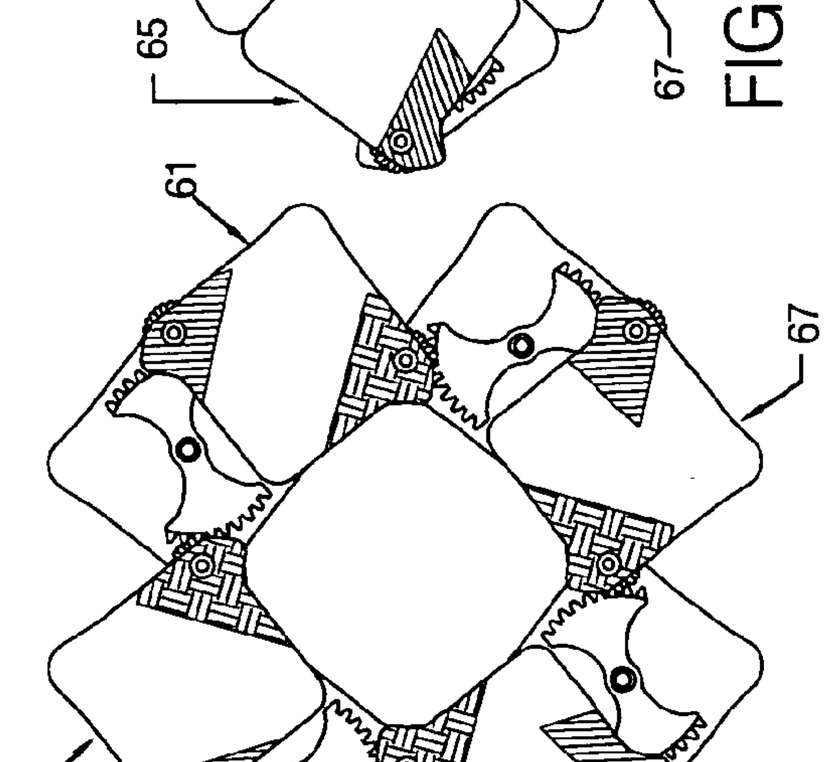


FIG.18

FIG.19

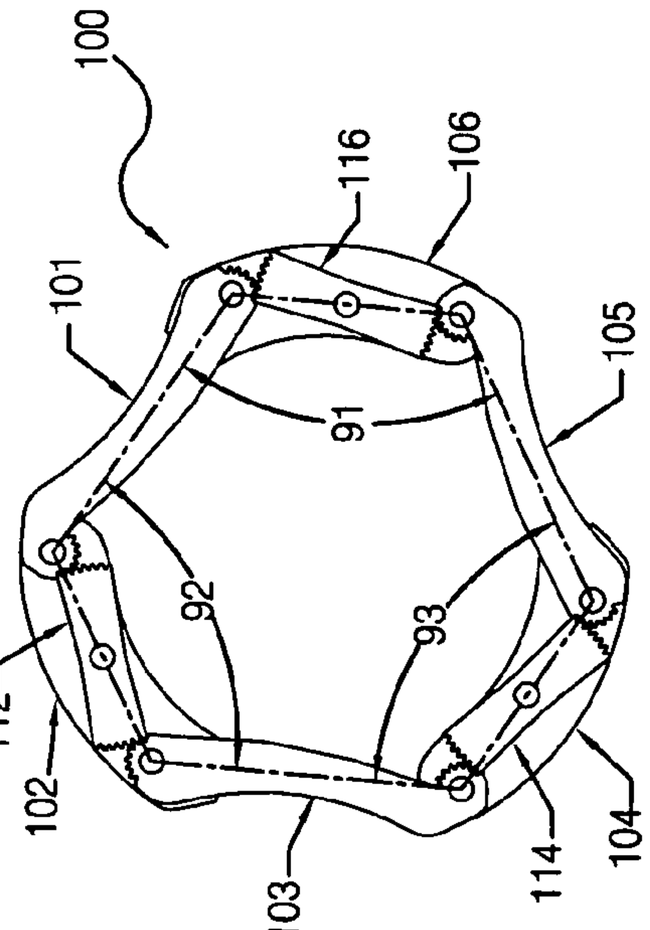


FIG.22

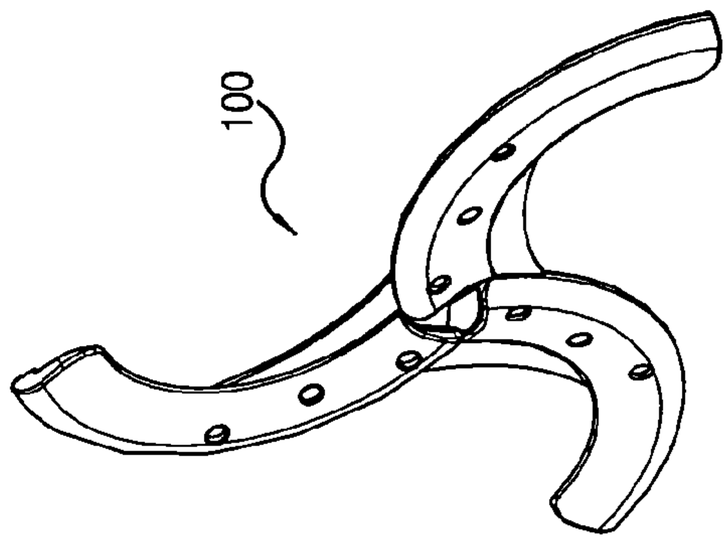


FIG.26

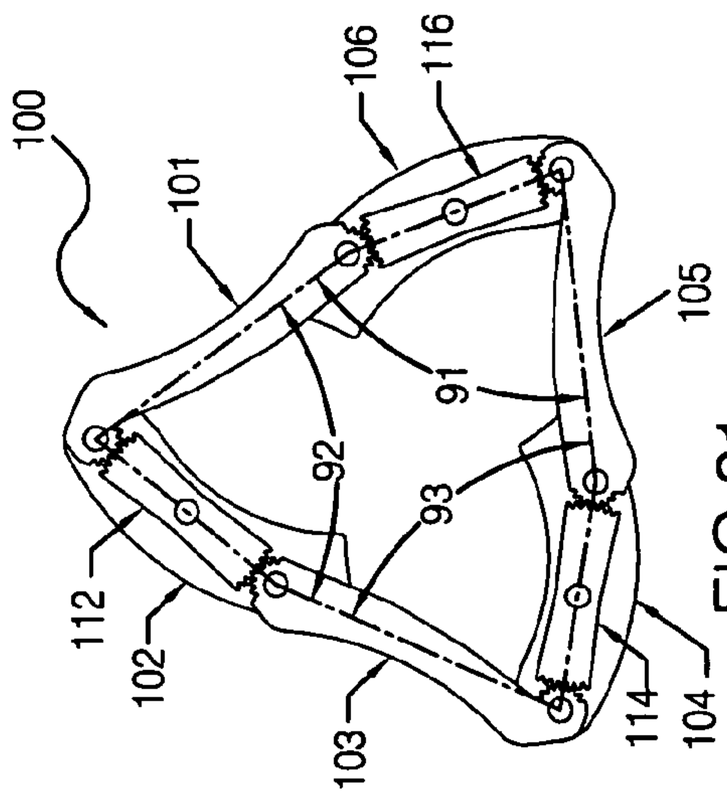


FIG.21

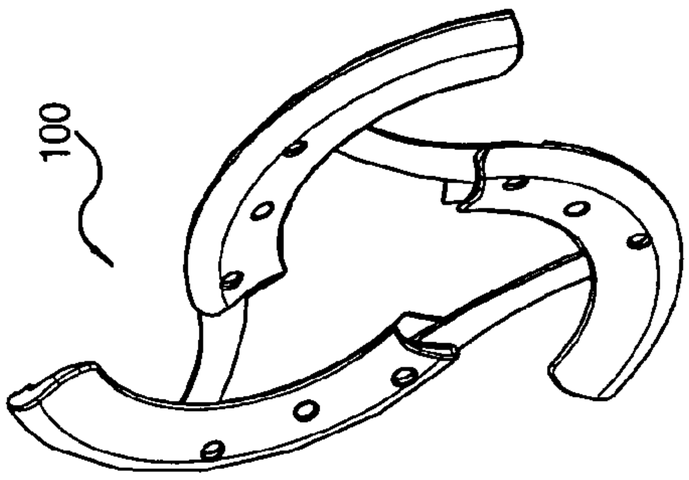


FIG.25

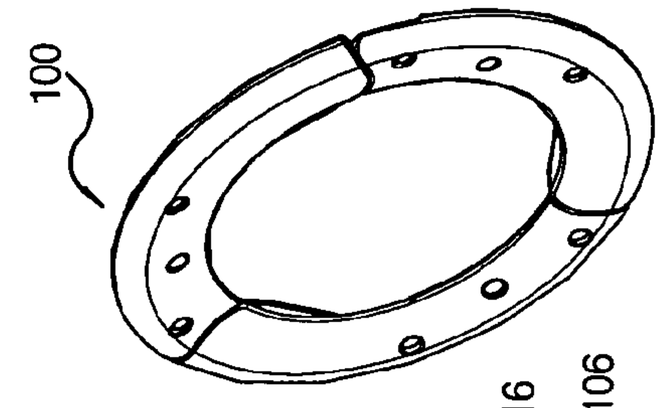


FIG.24

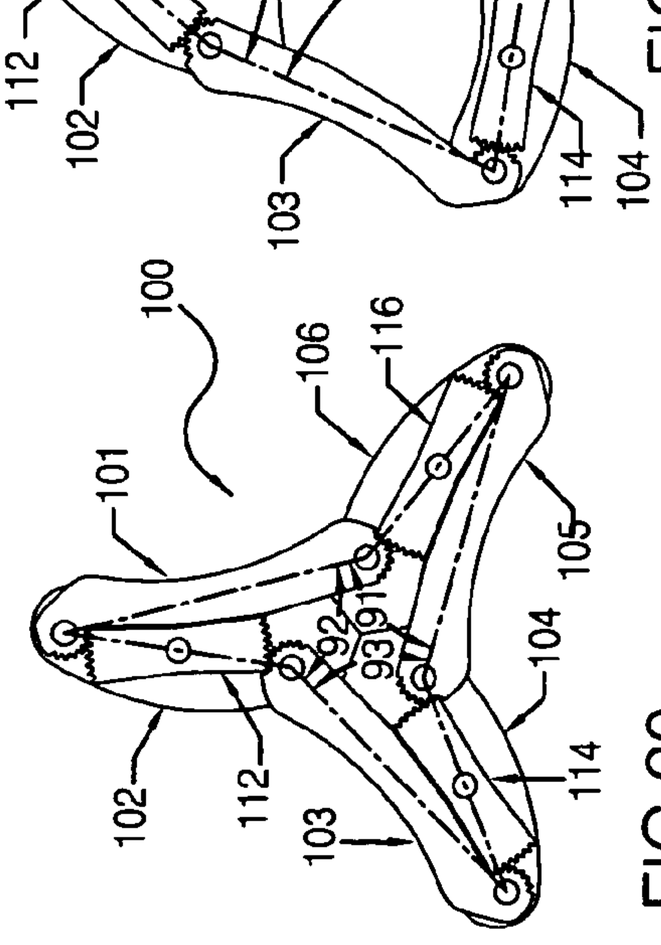
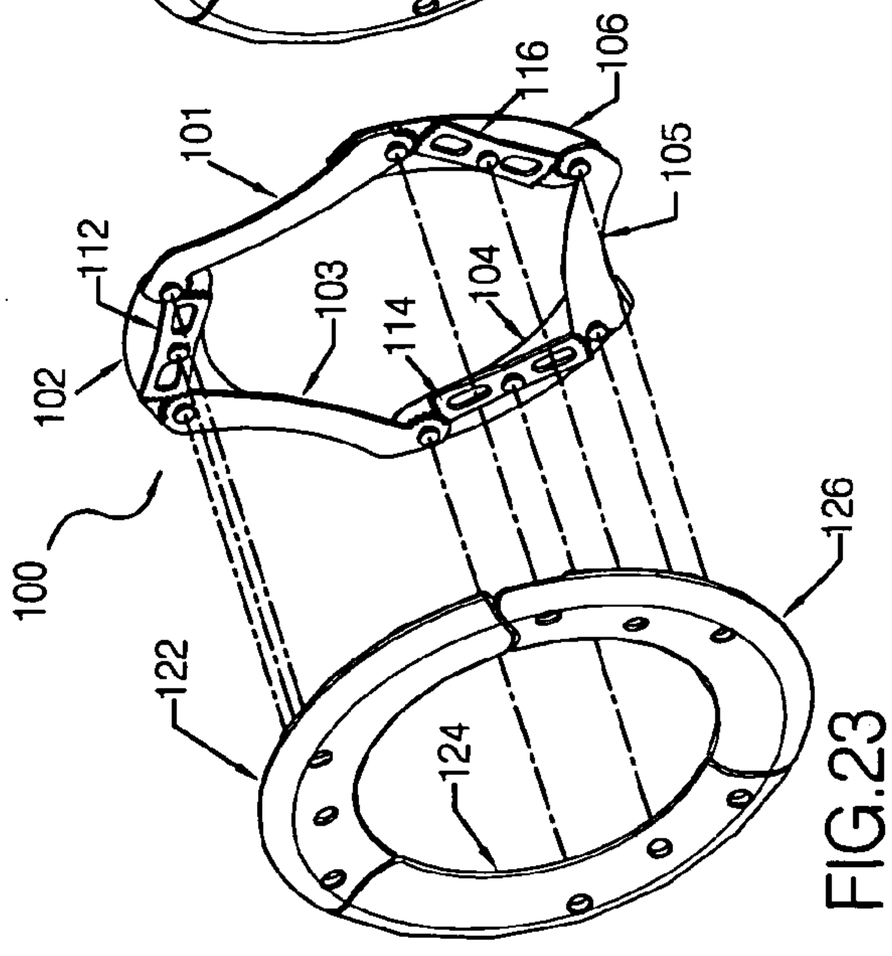


FIG.20



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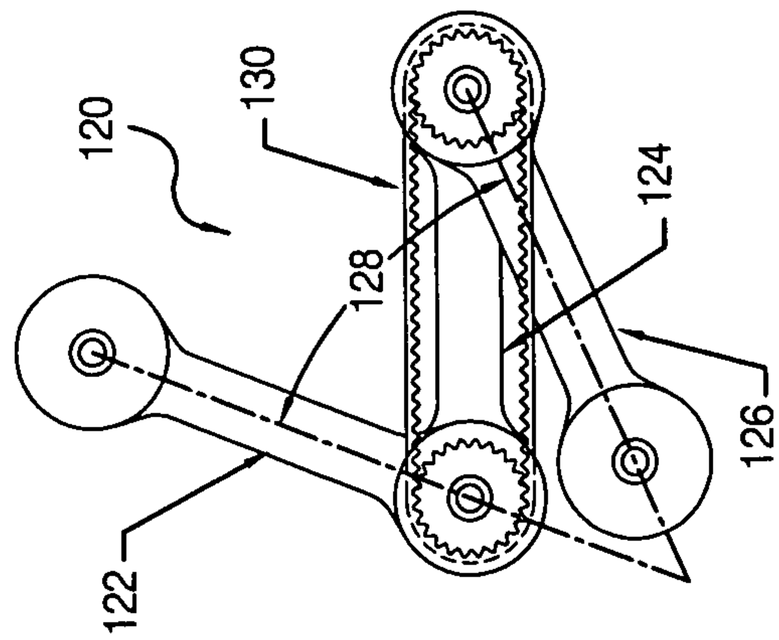

FIG.30

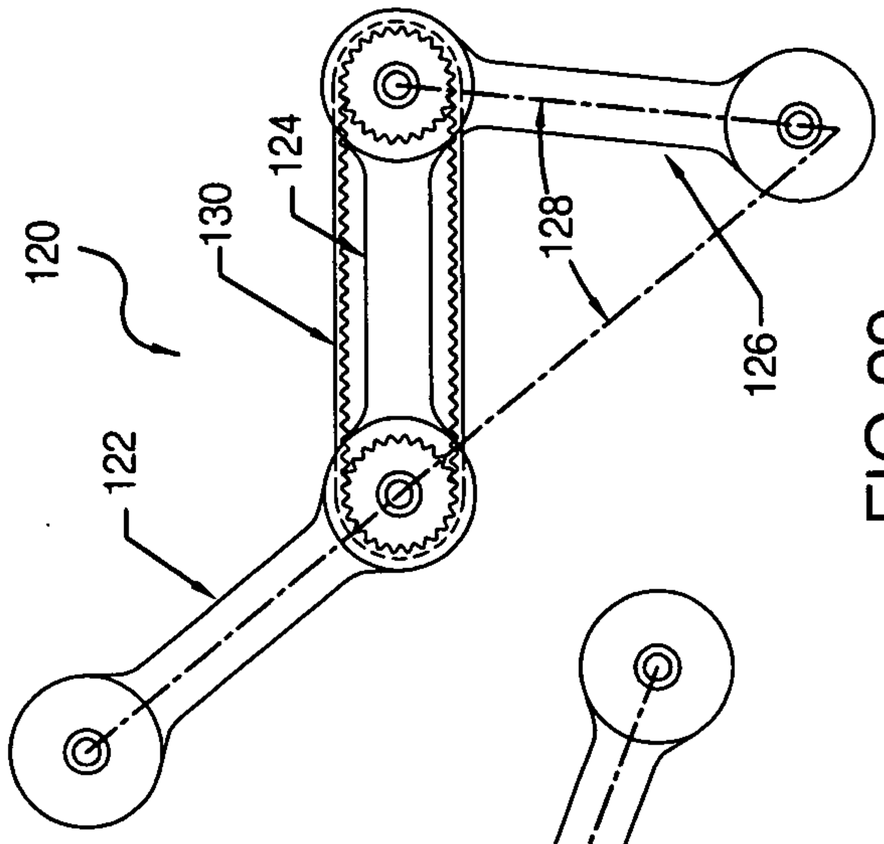

FIG.29

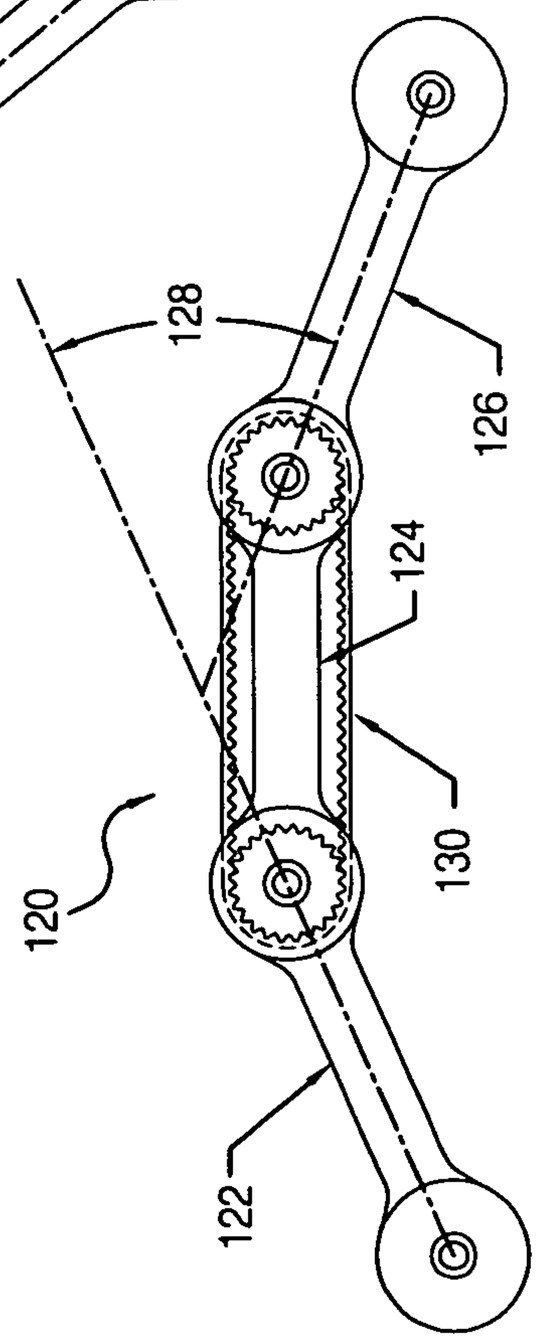

FIG.28

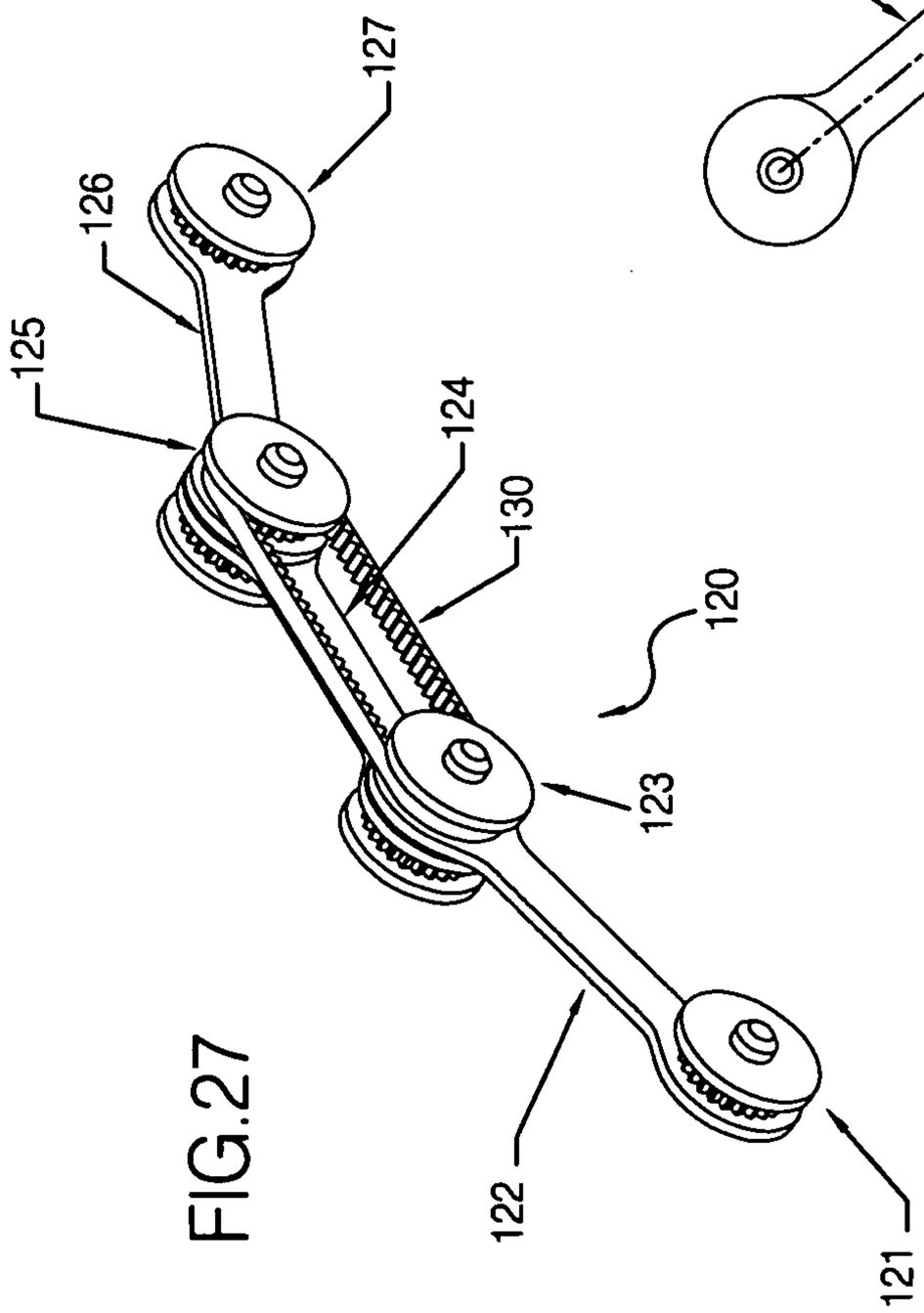

FIG.27

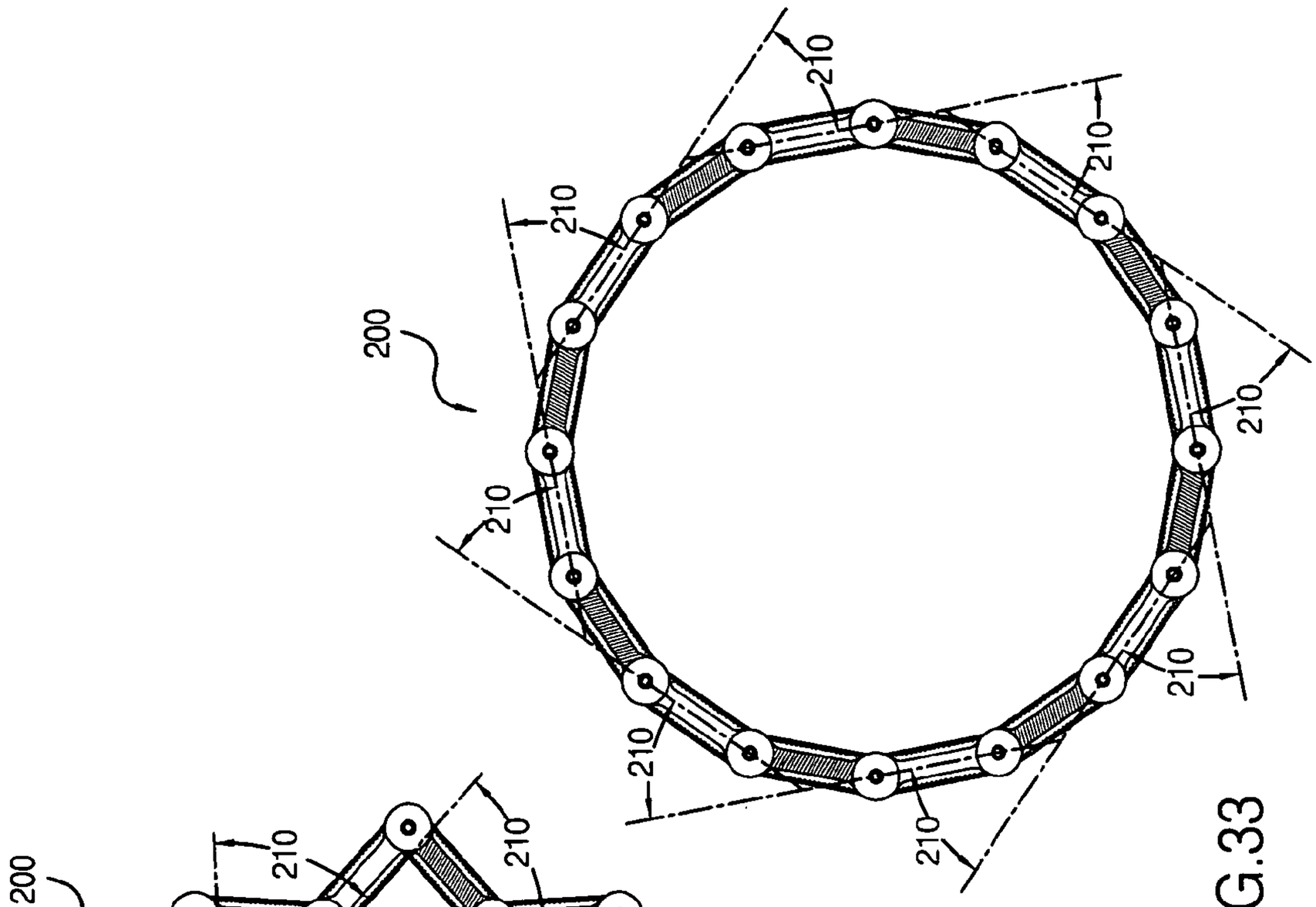

FIG.33

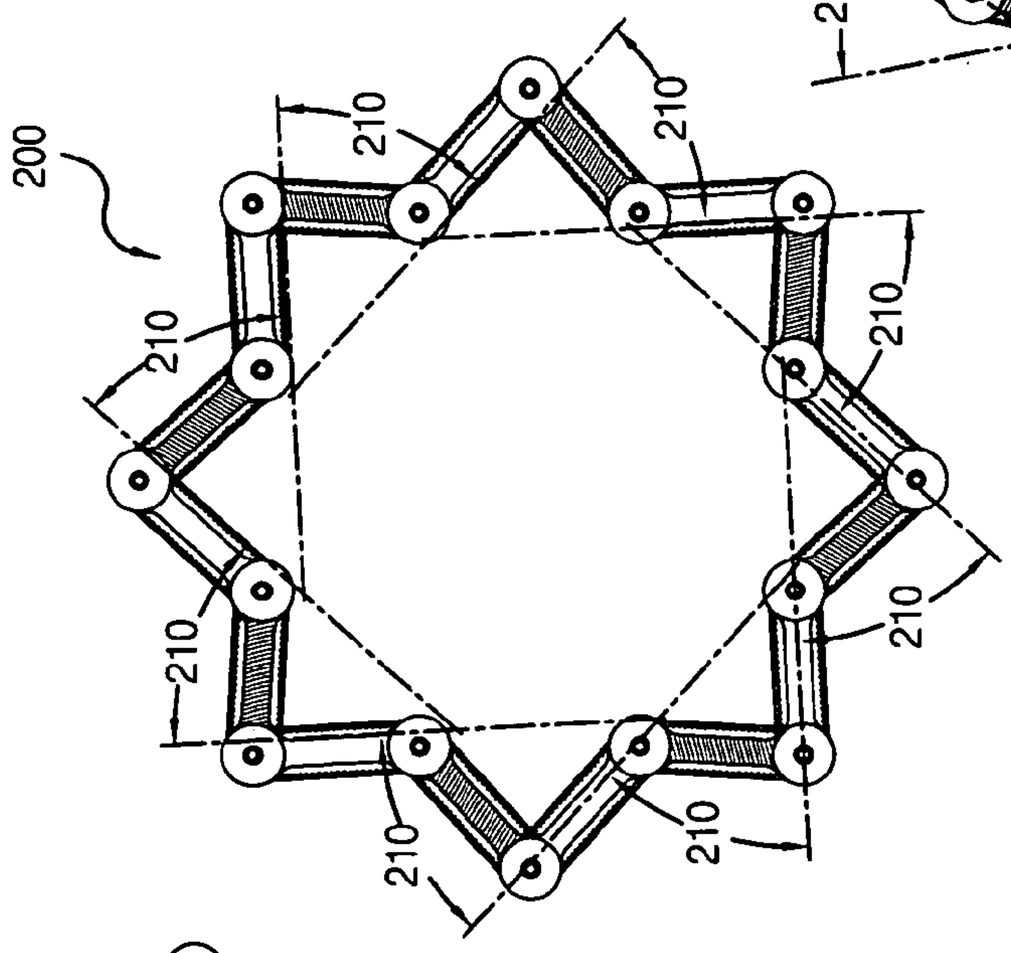

FIG.32

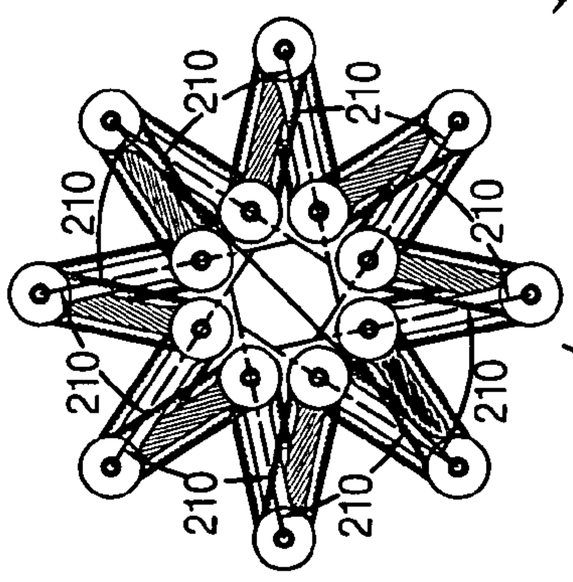

FIG.31

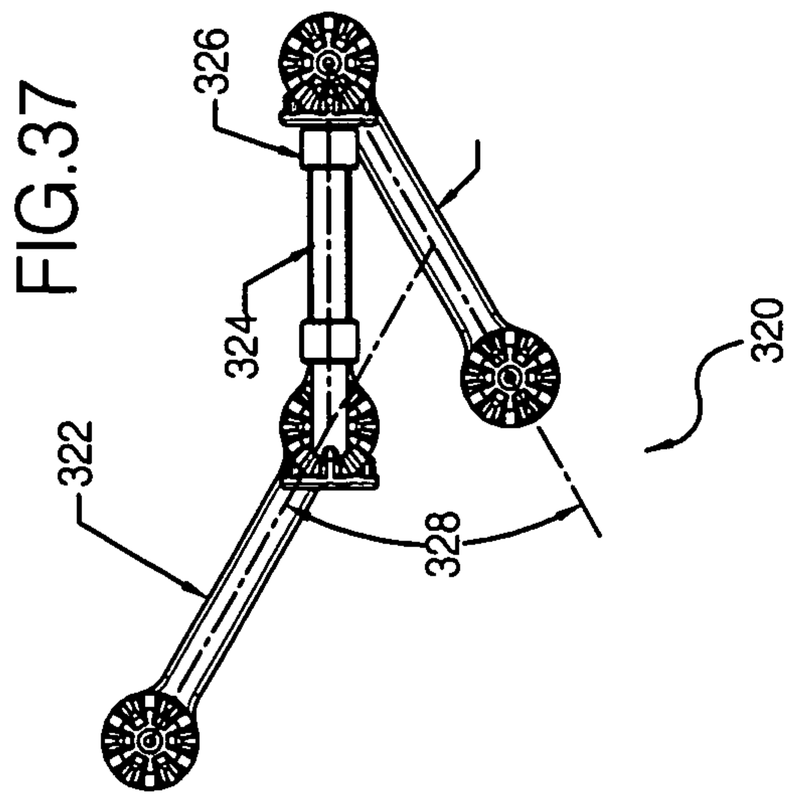

FIG.37

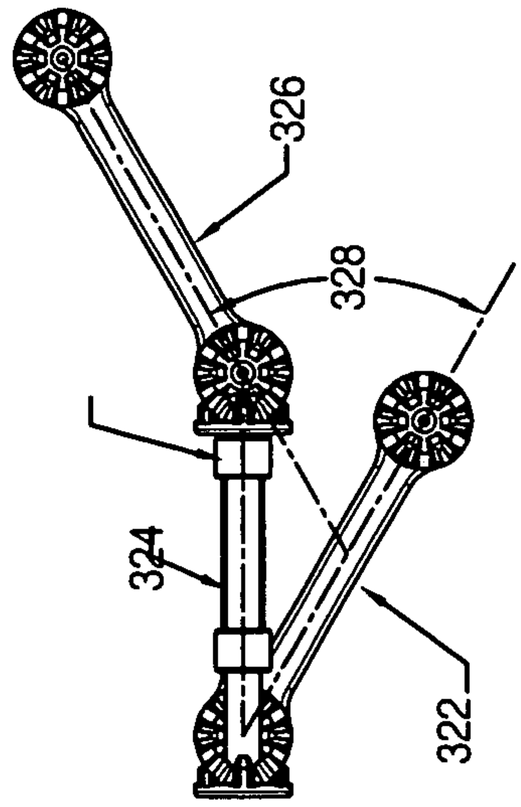

FIG.36

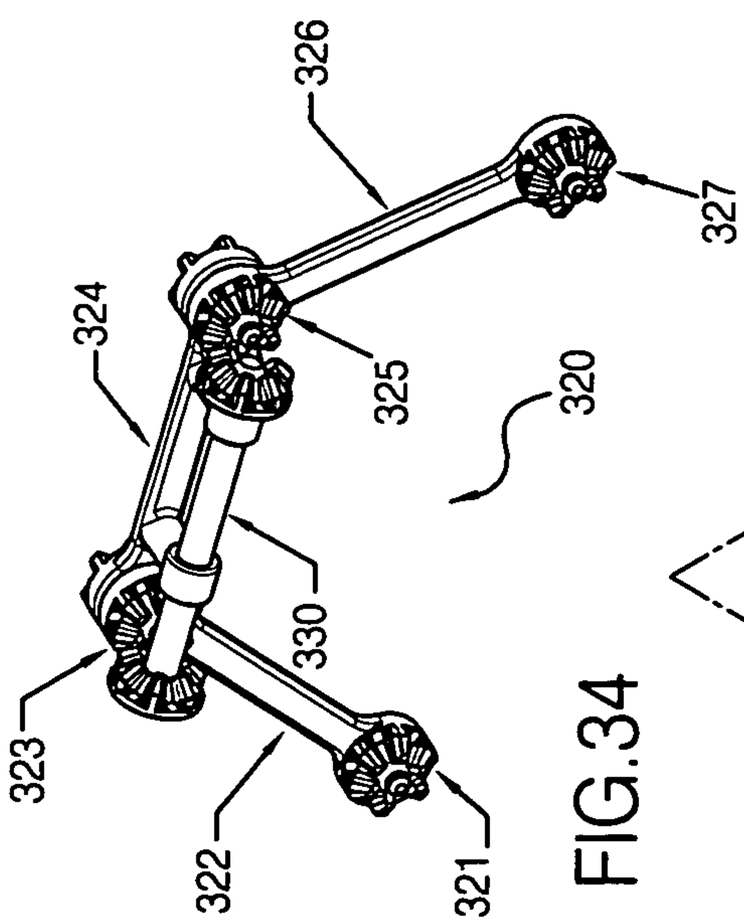

FIG.34

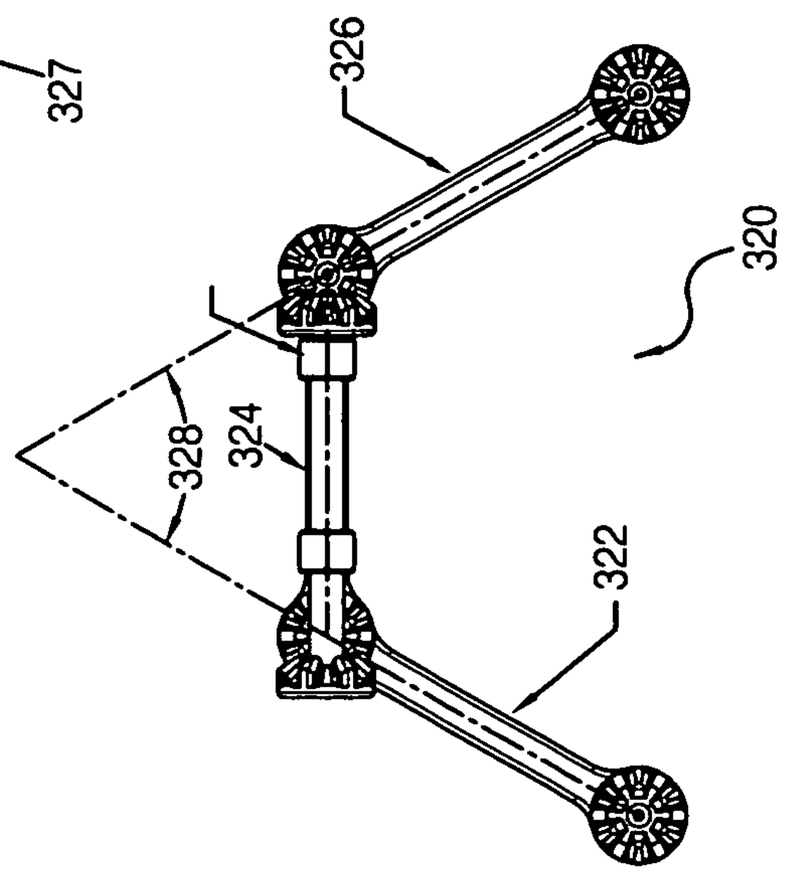

FIG.35

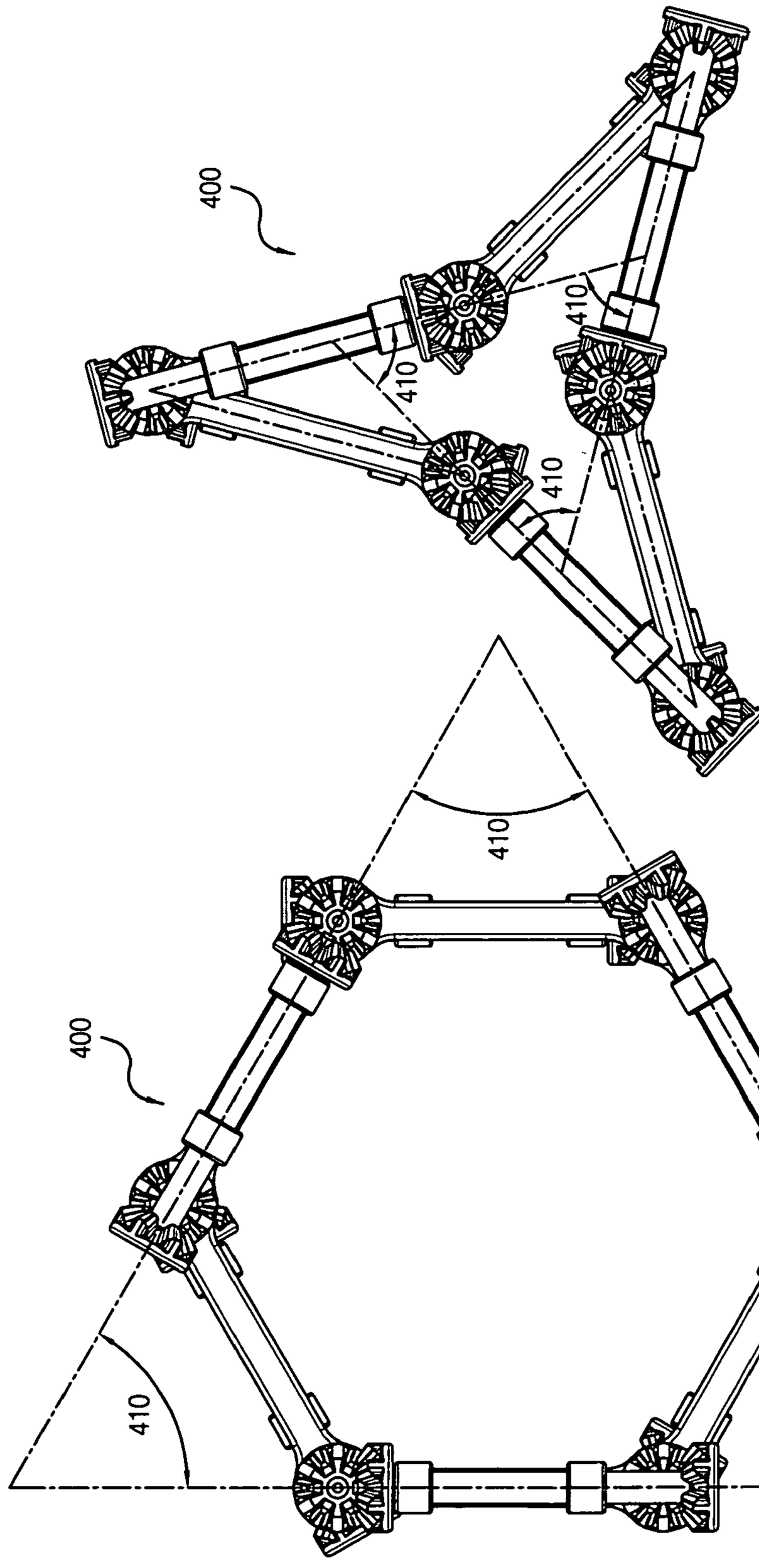

FIG.39

FIG.38

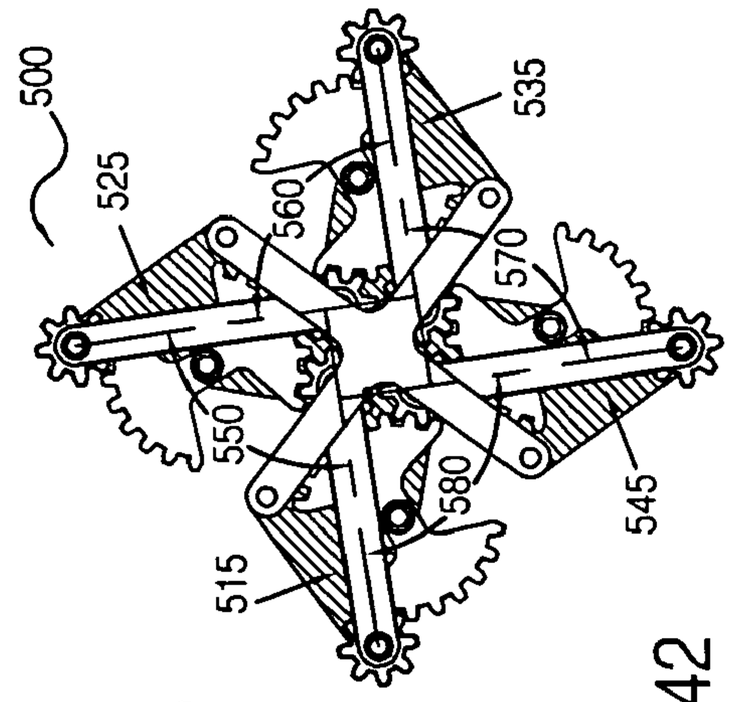

FIG.42

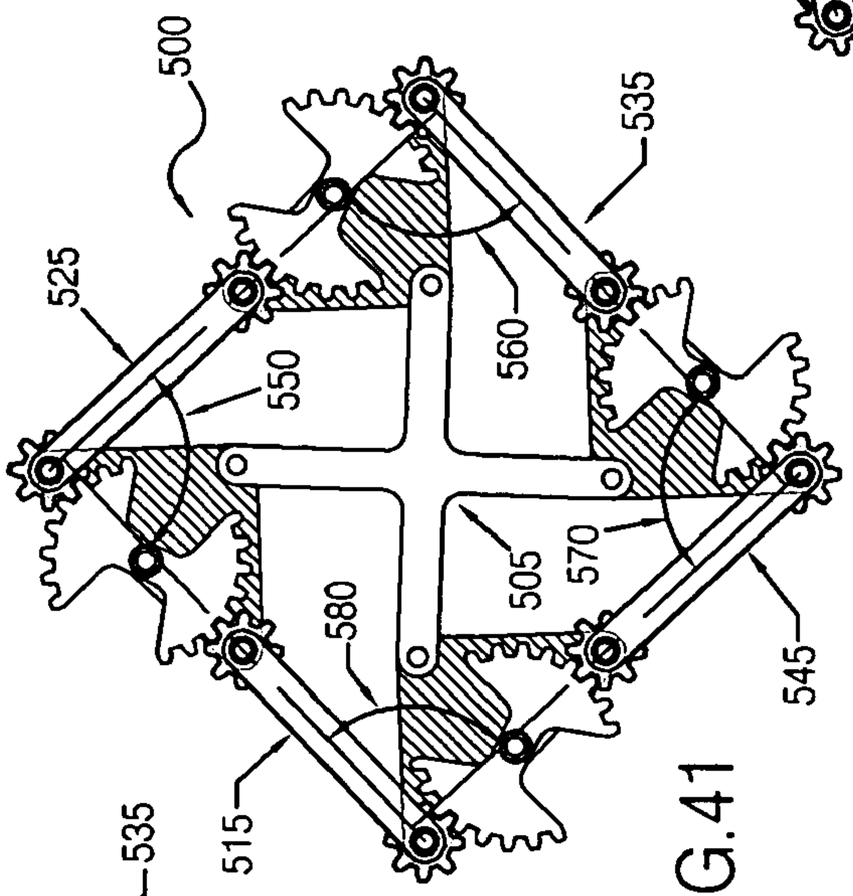

FIG.41

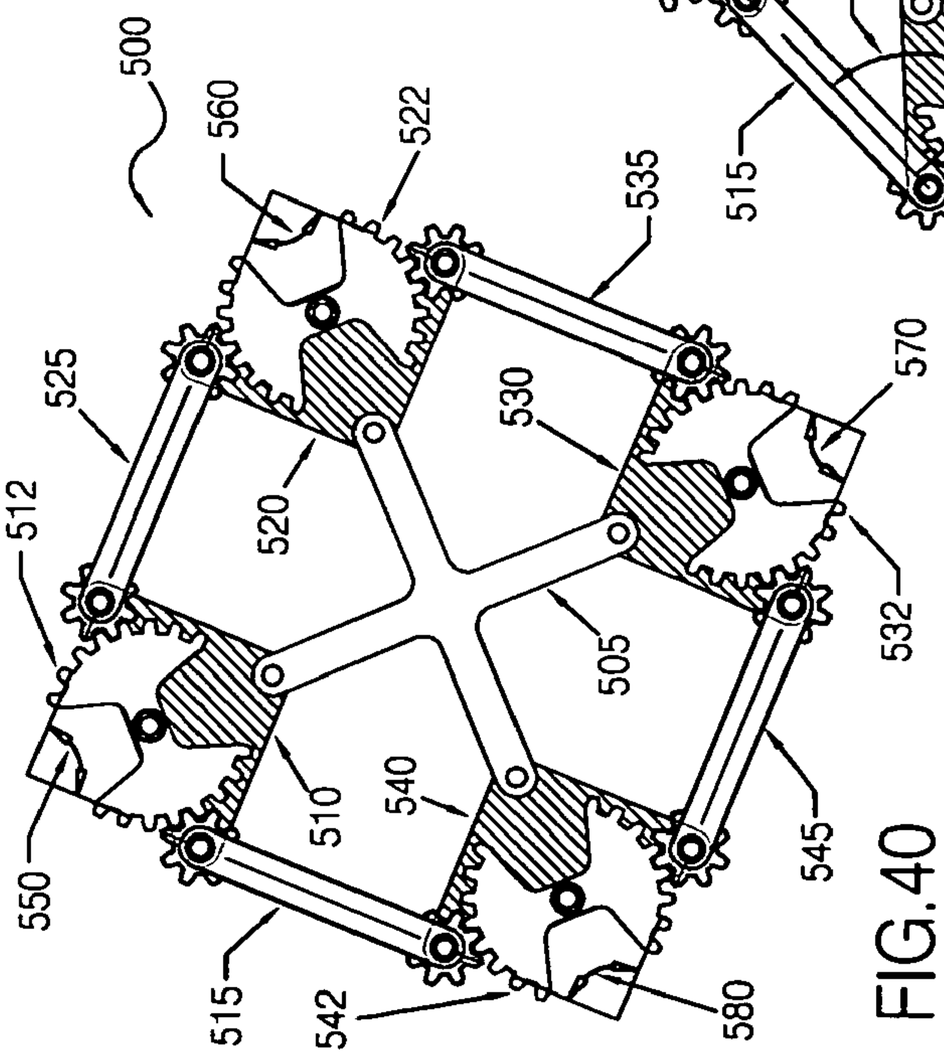

FIG.40

SYNCHRONIZED RING LINKAGES

This application is based on and claims priority of provisional application Ser. No. 60/512,633, filed Oct. 20, 2003

U.S. Pat. No. 5,024,031 hereby incorporated by reference as if fully disclosed herein teaches methods for constructing transformable truss-structures in a variety of shapes. The teachings therein have been used to build structures for diverse applications including architectural uses, public exhibits and unique folding toys.

One basic embodiment disclosed in U.S. Pat. No. 5,024,031 are loop-assemblies comprised of scissor-pairs which are in turn comprised of angulated strut elements. Such loop-assembles are foldable in the sense that they expand and contract in a synchronized fashion when a relative motion is imposed between any two links.

BACKGROUND OF THE INVENTION

SUMMARY OF THE INVENTION

In accordance with the present invention, a new way to create loop assemblies comprised of links pivotally joined end to end such that the motion of the assembly is provided. The synchronization may be accomplished in a variety of methods such as gears, belts or pulleys. All methods have in common the linking of every second link in the loop assembly such that the relative rotation of every second link is synchronized.

One key benefit of the invention is a reduction in the number of individual elements as compared with those structures disclosed in U.S. Pat. No. 5,024,031. Rather than all links being "doubled" in the form of scissor-pairs, a single loop of links suffices. The addition of gears or pulleys represents only minor additional material.

The invention has a second useful feature as well. For structures disclosed in '031, they move between a contracted state and expanded state. As the structure expands, its members rotate approximately ninety degrees. When the structure is fully expanded, the members are prevented from rotating further because the hub elements contact each other.

According to the current invention, structures are disclosed such that its members rotate approximately one hundred and eighty degrees. Thus, the structure starts in a contracted state, where its members are in a radial configuration, to an expanded state where its members form an extended loop, and then it can be continuously folded again so that it reaches a second, unique contracted state.

This unusual ability to "flip" between two unique folded states allow for structures to be built that display a pleasing visual transformation.

A third useful feature of the current invention is that it provides a mechanism whereby a circular ring that has flight on characteristics can transform into a boomerang.

It is thus an object of the invention to provide an improved ring linkage system.

Another object of the invention is to provide a linkage system whose motion is synchronized.

Yet a further object of the invention is to provide an improved linkage having a plurality of links in geared contact with one another.

Other objects and advantages of the invention will, in part, be obvious and will, in part, be apparent from the following description.

BRIEF DESCRIPTION OF THE DRAWINGS

For a fuller understanding of the invention, reference is made to the following description, taken in connection with the accompanying drawings in which:

FIG. **1** is a perspective view of three links pivotally connected to each other and made in accordance with the invention;

FIG. **2** is a plan view of the three links of FIG. **1** in a partially folded condition;

FIG. **3** is a plan view of the three links of FIG. **1** in a partially extended condition;

FIG. **4** is a plan view of the three links of FIG. **1** in a third angled condition;

FIG. **5** is a perspective view of a first embodiment of the linkage assembly of the invention;

FIG. **6** is a plan view of the linkage of FIG. **5**;

FIG. **7** is also a plan view of the linkage assembly of FIG. **5** and similar to FIG. **6**;

FIG. **8** is a plan view of the linkage assembly of FIG. **5** shown in a different position;

FIG. **9** is a plan view of the linkage assembly of FIG. **5** in a folded condition;

FIG. **10** is a plan view of the linkage assembly of FIG. **5** and similar to FIG. **9**;

FIG. **11** is an exploded perspective view of a second embodiment of the linkage assembly of the invention;

FIG. **12** is a perspective view of the linkage assembly of FIG. **1** in a closed position;

FIG. **13** is a perspective view of the assembly of FIG. **11** in a partially open condition;

FIG. **14** is a perspective view of the linkage assembly of FIG. **11** in a fully open condition;

FIG. **15** is a plan view of the linkage assembly of FIG. **11**;

FIG. **16** is a plan view of the linkage assembly of FIG. **11** in a partially open condition;

FIG. **17** is a plan view of the linkage assembly of FIG. **11** in a fully open condition;

FIG. **18** is a plan view of the linkage assembly of FIG. **11** in a second partially open condition;

FIG. **19** is a plan view of the linkage assembly of FIG. **11** in a second closed condition;

FIG. **20** is a plan view of a third embodiment of a linkage assembly in accordance with the invention;

FIG. **21** is a plan view of the linkage assembly of FIG. **20** in a partially open condition;

FIG. **22** is a plan view of the linkage assembly of FIG. **20** in a fully open condition;

FIG. **23** is an exploded perspective view of covering panels suitable for attaching to the linkage assembly of FIG. **20**;

FIG. **24** is a perspective view showing the covering panels of FIG. **23** forming a ring;

FIG. **25** is a perspective view showing the covering panels of FIG. **23** in a partially open condition;

FIG. **26** shows the covering panels of FIG. **23** in a fully closed condition;

FIG. **27** is a perspective view of another linkage assembly made in accordance with the invention:

FIG. **28** is a plan view of the linkage assembly of FIG. **27** in an extended condition;

FIG. **29** is a plan view of the linkage assembly of FIG. **27** in a partially angled condition;

FIG. **30** is a plan view of the linkage assembly of FIG. **27** in a folded condition;

FIG. **31** is a plan view of still another embodiment of the linkage assembly made in accordance with the invention;

FIG. **32** is a plan view of the linkage assembly of FIG. **31** in a partially open condition;

FIG. **33** is a plan view of the linkage assembly of FIG. **31** in a fully open condition;

FIG. **34** is a perspective view of yet a further embodiment of the linkage assembly of the invention;

FIG. **35** is a plan view of the linkage assembly of FIG. **34**;

FIG. **36** is a plan view of the linkage assembly of FIG. **34** in a partially folded condition;

FIG. **37** is a plan view of the linkage assembly of FIG. **34** in an alternative folded condition;

FIG. **38** is a plan view of yet another embodiment of a linkage assembly of the invention;

FIG. **39** is a plan view of a linkage assembly of FIG. **38** in a partially closed condition;

FIG. **40** is a top plan view of a further embodiment of a linkage assembly of the invention;

FIG. **41** is a top plan view showing the linkage assembly of FIG. **40** in a different position; and

FIG. **42** is a top plan view showing the linkage assembly of FIG. **40** in yet another position.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. **1** shows a perspective view of mechanical assembly **10** consisting of three links **12**, **14** and **16** which are pivotally connected to each other end-to-end. Link **12** has two ends **11** and **13** each of which has a geared profile. Similarly the ends of link **16** has two ends **15** and **17** ends each of which have a geared profile.

Gear **18** is pivotally connected to link **14**. Gear end **13** engages with gear **18**; likewise gear end **15** engages with gear **18**.

FIG. **2** shows a plan view of assembly **10**. The two dashed lines shown passing through the end pivots of links **12** and **16** form an angle **15** between them.

FIG. **3** shows assembly **10** in a different position, links **12** and **16** having been rotated relative to link **14**. Links **12** and **16** form an angle **15** between them, said angle being unchanged from the angle shown in FIG. **2**. The reason that this angle remains unchanged is because gear **18** synchronizes the relative motion of links **12** and **16**.

FIG. **4** shows assembly **10** in a third position. The relative angle between links **12** and **16** remains unchanged.

FIG. **5** shows a perspective view of linkage **30** which is comprised of eight links **31**,**32**,**33**,**34**,**35**,**36**,**37** and **38** which are pivotally connected end to end. Each link terminates with two gear ends. Gear **41** is pivotally attached to link **31**. Likewise gears **42**,**43**,**44**,**45**,**46**,**47** and **48** are respectively pivotally attached to links **32**,**33**,**34**,**35**,**36**,**37** and **38**.

The gear ends of link **31** engage with gears **48** and **42**. Likewise the gear ends of all the links engage with the gears which are pivotally attached to their neighboring links.

FIG. **6** shows linkage **30** in plan view. Links **31** and **33** are pivotally connected to link **32** and their respective gear ends are engaged with gear **42**. The dashed lines passing through

the end pivots of links **31** and **33** form an angle **51** between them. Similarly the dashed lines passing through link pairs **33-35**, **35-37** and **37-31** form angles **52**, **53** and **54** respectively.

FIG. **7** shows linkage **30** in the same view as FIG. **6**, with angles **55**,**56**,**57**,**58** being formed by the dashed lines passing through link pairs **32-34**, **34-36**, **36-38** and **38-32** respectively.

FIG. **8** shows linkage **30** in a different position. The angle **51** formed by the dashed lines passing through links **31** and **33** is unchanged from FIG. **6**. Likewise, the similarly formed angles **52**,**53** and **54** are unchanged from those formed in FIG. **6**.

FIG. **9** shows linkage **30** in a folded position. The four angles **51**,**52**,**53** and **54** respectively formed between link pairs **31-33**, **33-35**, **35-37** and **37-31** are unchanged from those formed in FIGS. **6** and **7**.

FIG. **10** shows linkage **30** in the same view as FIG. **9**. The four angles **51**, **52**, **53** and **54** respectively formed between link pairs **32-34**, **34-36**, **36-38** and **38-32** are unchanged from those formed in FIGS. **6** and **7**.

Thus linkage **30** demonstrates a key feature of the invention: the relative angle between two links that are each connected to a common link between them, and that are synchronized by a gear that is connected to said common link, will form a constant and unchanging angle for any given position of the linkage.

In FIG. **11**, an assembly **80** is shown in exploded view. Assembly **80** is comprised of eight links having a polygonal profile, one layer comprised of links **61**,**63** **65** and **67**; a second layer comprised of links **62**,**64**,**66** and **68**. Additionally eight gears **71**,**72**,**73**,**74**,**75**,**76**,**77** and **78** are pivotally connected respectively to the eight links.

FIG. **12** shows assembly **80** in a closed position whereby links **61**, **63**, **65** and **67** form a continuous surface. FIG. **13** shows assembly **80** in a partially open position and FIG. **14** shows **80** in its fully opened position.

FIG. **15** shows a assembly **80** in plan view. An image of a triangle **81** has been printed on links **61**, **63**, **65** and **67**. FIG. **16** and FIG. **17** show assembly **80** in a partially opened and fully opened position respectively.

FIG. **18** shows assembly **80** in a second partially opened position whereby the links have been rotated past their fully opened position. FIG. **19** shows assembly **80** in its second closed position. A second image of a square **82** has been printed on links **61**, **63**, **65** and **67**. Thus, assembly **80** is shown to have the capability to "flip" between two separate images.

FIG. **20** shows an assembly **100** comprised of six links **101**, **102**,**103**,**104**,**105** and **106** which are pivotally connected end to end. Three gears **112**, **114** and **116** are pivotally attached to links **102**,**104** and **106** respectively. Angles **91**,**92** and **93** are shown formed between link-pairs **105-101**, **101-103** and **103-105** respectively.

FIG. **21** shows assembly **100** in a partially opened position. The angles between link pairs **105-101**, **101-103** and **103-105** are respectively **91**,**92** and **93** being unchanged from FIG. **20**.

FIG. **22** shows assembly **100** in a fully opened position. The angles between link pairs **105-101**, **101-103** and **103-105** are respectively **91**,**92** and **93** being unchanged from FIGS. **20** and **21**.

FIG. **23** shows assembly **100** in exploded view with three covering panels **122**, **124** and **126** shown. FIG. **24** shows these covering panels attached to links **102**, **104** and **106** respectively such that a ring is formed when **100** is in its fully opened position. Said ring has certain flying characteristics for straight sustained flight when thrown in a spinning motion.

FIG. **25** shows assembly **100** with its attached covering panels shown in a partially opened position. FIG. **26** shows assembly **100** in its fully closed position such that it forms the profile of a three pronged shape. Said shape has certain flying characteristics similar to a boomerang when thrown with a spin such that it flies in a loop returning to the thrower.

FIG. **27** shows a perspective view of mechanical assembly **120** consisting of three links **122**, **124** and **126** which are pivotally connected to each other end-to-end. Link **122** has two ends **121** and **123** each of which have an attached pulley. Similarly, the ends of link **126** has two ends **125** and **127** ends each of which have an attached pulley.

Belt **130** engages pulley ends **123** and **125**. FIG. **28** shows a plan view of assembly **120**. The two dashed lines shown passing through the end pivots of links **122** and **126** form an angle **128** between them.

FIG. **29** shows assembly **120** in a different position, links **122** and **126** having been rotated relative to link **124**. Links **122** and **126** form an angle **128** between them, said angle being unchanged from the angle shown in FIG. **28**. The reason that this angle remains unchanged is because belt **130** synchronizes the relative motion of links **122** and **126**.

FIG. **30** shows assembly **120** in a third position. The relative angle **128** between links **122** and **126** remains unchanged.

FIG. **31** shows a loop assembly **200** comprised of sixteen links, each having two pulley ends, every other link being connected via a belt such that a constant angle **210** is formed between every other link. FIG. **32** shows assembly **200** in a different position where the angle **210** between every second link is unchanged.

FIG. **33** shows assembly **200** in its fully opened position, the angle **210** between every second link remaining unchanged.

FIG. **34** shows a perspective view of mechanical linkage assembly **320** consisting of three links **322**, **324** and **326** which are pivotally connected to each other end-to-end. Link **322** has two ends **321** and **323** each of which have an attached bevel gear. Similarly the ends of link **326** has two ends **325** and **327** ends each of which have a geared an attached bevel gear.

Gear assembly **330** comprised of two bevel gears fixed to a common shaft is pivotally connected to link **324** and engages bevel gear ends **323** and **325**. FIG. **35** shows a plan view of assembly **320**. The two dashed lines shown passing through the end pivots of links **322** and **326** form an angle **328** between them.

FIG. **36** shows assembly **320** in a different position, links **322** and **326** having been rotated relative to link **324**. Links **322** and **326** form an angle **328** between them, said angle being unchanged from the angle shown in FIG. **35**. The reason that this angle remains unchanged is because gear assembly **330** synchronizes the relative motion of links **322** and **326**.

FIG. **37** shows assembly **320** in a third position. The relative angle **328** between links **322** and **326** remains unchanged.

FIG. **38** shows a linkage or loop assembly **400** comprised of six links, each having two bevel gear ends, every other link being connected via a bevel gear assembly such that a constant angle **410** is formed between every other link.

FIG. **39** shows assembly **200** in a different position where the angle **410** between every second link is unchanged.

FIG. **40** shows an assembly **500** which is comprised of four links **515**, **525**, **535** and **545** each having two gear ends, four links **510**, **520**, **530** and **540** having a triangular profile and three pivots each. Four gears **512**, **522**, **532** and **542** are pivotally attached to links **510**, **520**, **530** and **540** respectively. Assembly **500** further includes a central link **505** which is pivotally connected to the third pivot each of links **510**, **520**, **530** and **540**. Central link **505** serves to assist in the synchronization of assembly **500**.

An angle **550** is formed between links **515** and **525**. Similarly, angles **560**, **570** and **580** are formed between link-pairs **525**, **535**; **535**, **545**; and **545**, **515** respectively.

FIG. **41** shows assembly **500** in a different position. The angle **550** formed between links **515** and **525** is unchanged from FIG. **40**. Similarly, angles **560**, **570** and **580** are formed between link-pairs **525**, **535**; **535**, **545**; and **545**, **515**, and are unchanged from FIG. **40**.

FIG. **42** shows assembly **500** in another position. Angles **550**, **560**, **570** and **580** are formed between link-pairs **515**, **525**; **525**, **535**, **535**, **545**; and **545**,**515**, and are unchanged from FIGS. **40** and **41**.

It will thus be seen that the objects set forth above, among those made apparent from the proceeding description, are efficiently attained, and, in since certain changes may be made in the construction of the inventive structure without departing from the spirit and scope of the invention, it is intended that all matter contained in the above description and shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

It is also to be understood that the following claims are intended to cover all of the general and specific features of the invention described herein and all statements of the scope of the invention which, as a matter of language, might be said to fall there between.

The invention claimed is

1. A ring linkage comprising at least six links, each link having a first end and a second a opposite end, each link including a pivot located proximate to each said end, said links being arranged in a loop configuration such that each link is pivotally attached at its pivots to said first ends of two adjacent non-joined links;

wherein at least two of said links each includes means connected between said first ends of its two adjacent non-joined links for synchronizing the relative rotation of said non-joined links such that when one adjacent link rotates in one rotational direction by a given angle the other link rotates in the same rotational direction and by the same angle.

2. The linkage of claim **1**, wherein said synchronizing means is selected from the group consisting of gears, cables and belts.

3. The linkage of claim **1**, wherein each link has two geared ends.

4. The linkage of claim **3**, wherein each geared end of each said link engages a geared end of an adjacent link.

5. The linkage of claim **1**, wherein each link has an attached pully at either end.

6. The linkage of claim **5**, wherein said every other link in the ring linkage is defined by a belt for engaging the attached pully at the end of each adjacent link.

7. The linkage of claim **1**, wherein each link has an attached beveled gear at either end.

8. The linkage of claim **1** wherein said every other link in the ring linkage is connected to its adjacent links by a bevel gear assembly.

9. The linkage of claim **1** wherein at least some of said links includes a covering panel.

10. The linkage of claim **1**, wherein said two adjacent links of said each link define a link pair having an angle therebetween that remains constant when said linkage is manipulated between a first closed condition and a second open condition.

11. The linkage of claim **10**, wherein said linkage has a profile of at least a three prong shape when in a fully closed condition.

12. The linkage of claim **1**, wherein at least one covering panel covers all of said links such that a ring is formed when said linkage is in a fully open condition.

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